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ECL-31

PRECISION INSTRUMENT CORPORATION
Experience with a Tape Reel Hold-down Mechanism

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EXHIBITS

Mr. Stewart Smith, Vice-President in charge of engineering at the Precision Instrument Corporation in Palo Alto, California, recently told a Stanford case-writer, "We have designed several reel hold-down knobs for our PI-200 magnetic tape recorders, but in my opinion, a better hold-down mechanism is still needed." He said this problem prevails throughout the tape recorder industry, observing, "Every major manufacturer of instrumentation tape recorders has at some time invested much time and money trying to design a satisfactory hold-down mechanism. The main problem with the PI-200 hold-down knob is that it is too expensive."

Prepared in the Design Division, Department of Mechanical Engineering, Stanford University, by Robert D. Regier, with financial support from the National Science Foundation. Helpful cooperation of the Precision Instrument Corporation is gratefully acknowledged.

PI's[1] major products (shown in Exhibit 1) consist of miniature recorders for use in space vehicles or other applications where low size and weight are necessary, compact portable recorders, and larger laboratory recorders. The PI-400A recorder is frequently used at missile stations and aboard ships to record telemetering signals transmitted from missiles. The PI-6100 industrial and medical recorder has often been used to record chemical process data. This recorder is able to reproduce such data in one-tenth or one-hundredth of the time required for recording. PI's most portable recorder is the PI-5100. It weighs 35 pounds and can record continuously on one reel of tape for 10 days. Its power requirement is 7.5 watts at 12 volts D.C. The RSL-150-7 is a special purpose digital recorder which moves tape only when it receives information. This recorder is often used to record numbers dialed from telephones, its automatic shut-off feature allowing numbers to be recorded on a minimum amount of tape. The PI-3V video recorder is used by hospitals to record surgery with closed circuit television for subsequent observation in the classroom. PI recorders range in price from $4,000 to $50,000 per unit. They are electrically and mechanically more complex than home or professional audio recorders.

Mr. Smith supervises 20 mechanical and electrical engineers who design all PI products. Each major design project is supervised by a project engineer. Draftsmen and technicians assist the engineers, and machinists are available to build prototypes. The company's production division manufactures all major products and maintains quality control. All sheet metal work is contracted to outside firms.

Series PI-200 Recorders

PI-200 recorders range in price from $10,000 to $13,000, the price increasing with the number of recording tracks and speeds, and approximately 65% of all sales are to the U.S. Government. PI-200 recorders are used when high quality performance (similar to that of the PI-400) and portability are required. They are used as portable field units and in submarines, aircraft, and data acquisition laboratories.

The reels on 200 series recorders are mounted in a tape magazine. Tape changes may be accomplished in a few seconds by removing a magazine from the recorder and installing another one. All tape "re-threading" may be done in the magazine before or after it is attached to the recorder. The magazine is opened like a book to change reels. Reels are secured to their supporting turntables by hold-down mechanisms which are an integral part of the magazine. After a magazine is unfolded, tape is threaded from one reel to the other, and the magazine is closed before mounting it on the recorder as illustrated by Exhibit 2. Two concentric coupling shafts, extending outside the tape magazine, mate with shafts on the recorder front panel which are connected to a reel drive motor.

The primary purpose of the tape transport (reels, tape guides, driving motors, etc.) is to move tape across the magnetic heads at a precise location and speed. The magnetic heads and front portion of the tape driving mechanism are shown in Exhibit 3. Deviations in tape speed

[1] PI is the abbreviation for Precision Instrument Corporation.

must be minimized to obtain the highest quality of recording and reproduction. The tape transport should allow recording at several useful speeds and permit fast rewinding in both forward and reverse directions. During starting and stopping, tape tension must be maintained to prevent jamming due to tape slack.

During recording and playback, tape travels from the supply reel to the record and reproduce heads, then across a capstan, and then to the takeup reel. The tape is driven, during recording and playback, by the capstan whose speed is accurately regulated by a hysteresis motor in the precision drive assembly. Tape is gripped between an idler pulley (pressure roller) and the capstan during record and playback operation, thereby being moved at the speed of the capstan periphery. Guides hold the tape against the heads for recording and playback and allow it to lift from the heads during fast forward and rewind. The capstan touches the tape only during recording and reproduction, i.e., during "slow" forward tape motion. During "fast" winding, both forward and reverse, the capstan does not contact the tape, and, consequently, does not control tape speed. Tape is simply pulled from one reel to the other at a speed determined by the reel drive motor.

The reel drive system maintains tension in the tape as it is metered between capstan and pressure roller during recording and playback. The system also drives the tape during rewind in either the forward or reverse direction for fast rewinding and maintains tension to prevent tape slack or jamming when stopping the reels. Each drive shaft is connected to a pulley in the reel drive system as illustrated by Exhibit 4 (item 5). Depending on the operating mode, each pulley is either driven by the reel drive torque motor or braked by cord brakes. The torque motor, item 40 of Exhibit 4, rotates in one direction for forward tape motion and in the other direction for reverse winding. Coupling between the torque motor pulley, item 31, and reel drive pulleys, item 5, is accomplished by two rubber pucks, item 33, which are individually controlled by solenoids, items 51. The pucks are located at different distances from the front panel and each provides coupling to one of the reel drive pulleys. Coupling to the takeup reel drive shaft is provided when a solenoid forces the front-most puck against the front portion of the torque motor pulley and the takeup reel drive pulley. Coupling to the supply reel drive shaft is similarly accomplished by the other puck. Thus, during forward tape motion, the torque motor is coupled to the takeup reel drive shaft; during reverse winding, this motor is coupled to the supply reel shaft.

For recording and reproducing, A.C. power to the torque motor is reduced below that which is available for fast winding by switching a resistor into the motor circuit. Direction of torque motor rotation is determined by the polarity of voltage across the torque motor windings. Pushbuttons on the front panel operate relays which control these circuits.

The tape may be decelerated by the braking action of two dacron cords, items 11 and 14, which can be forced against the reel drive pulleys, item 5, by a solenoid. Greater braking force is applied to the reel supplying the tape to prevent tape slack. A retarding torque is applied

to the supply reel during continuous forward motion by another solenoid-controlled braking cord, item 16, that wraps around the supply pulley.

During recording, an amplifier forces a current through the record heads. The amplitude and phase of the current are a function of the signal being recorded. The magnetic field thus created magnetizes iron oxide particles on the tape as a function of the original signal. During reproduction, the changing magnetic flux created by the tape induces a voltage in the coils of the reproduce heads as a function of the recorded signal and tape speed. The magnitude and frequency of reproduce head voltage is dependent on the speed with which flux cuts the coil. Thus, transient variations of tape speed during reproduction will cause unwanted changes in the frequency and voltage of reproduce head output. Deviations from the desired tape speed must, therefore, be minimized during recording and reproduction. (Specific design objectives relating to this problem will be given later.)

Most electronic components in the record and playback amplifiers are mounted in the electronics housing assembly which appears in Exhibit 5. It contains keyed connectors for printed circuit cards and guide rails to simplify their insertion. Input, output, and test connectors are also part of the electronic housing. Air brought in by a blower through the bottom of the cabinet cools the equipment and exhausts through the top.

Tape Magazine

Different versions of tape magazines for PI-200 recorders will accommodate tape widths of 1/4", 1/2", or 1". When one or two tracks are recorded, 1/4" tape may be used. It is possible to record up to seven tracks on 1/2" tape and 14 tracks on 1" tape. The Scotch Precision tape reel manufactured by the Minnesota Mining and Manufacturing Company is typical of the reels used on PI-200 recorders. Some specifications for these reels appear in Exhibit 6. Recorders built to transport Precision reels are also compatible with most other types of reels used on instrumentation recorders.

A flange on each corner of the magazine back plate is shown in Exhibit 2. These are used to secure the magazine to the recorder front plate. The bottom flanges hook behind a stationary supporting bar on the front plate. When mounting the magazine, the bottom flanges are first slid behind the stationary supporting bar as shown in the lower photograph of Exhibit 1. The top of the magazine is then swung towards the recorder front plate until spring loaded bars snap over the upper flanges. The flanges and supporting bars only approximately locate the magazine on the recorder front panel. Precise magazine positioning necessary to align the turntable coupling shafts is provided when a ring-shaped protrusion on the back of the magazine, shown in Exhibit 8, fits into a hole in the recorder front plate, partially visible in Exhibit 7. The ring is chamferred to provide smooth entrance into the positioning hole.

The magazine back plate and magazine cover are held together by a hinge which is visible in Exhibit 2. A bracket is bolted onto the magazine back plate as one of the hinged members. The bracket contains two pins secured by set screws which pivot inside two holes in the magazine cover, the other hinged member.

If mounting holes for the turntables are drilled in the magazine before the magazine is assembled, variations in hinge dimensions will cause the takeup and supply turntables to be misaligned. PI engineers found that such variation could not be sufficiently minimized at a reasonable cost by machining the hinge to sufficiently small tolerances. To allow the use of less precise (and thus less expensive) machining, magazines were assembled before drilling the turntable mounting holes. The positioning hole in the recorder front plate was used as a "pilot" to locate properly the turntable mounting holes in the magazine back plate and cover. This procedure can result in accurately positioned turntables even though the hinge dimensions may vary from one magazine to another.

Some of the first PI-200 recorders were manufactured with the hinge shown in Exhibit 8; however, experience proved that this hinge was not sturdy enough and later models were made with the hinge appearing in Exhibit 2.

In Exhibit 9A, the supply turntable is shown. To mount a reel, the operator slides it onto the turntable so that three slots in the tape reel (9C) fit over three round plastic pins on the sides of the turntable (9B). The operator then locks the reel to the turntable by pressing his fingers against a ring on which the words "LOCK" and "RELEASE" are inscribed (9B) and by turning the ring to "LOCK" position. In "LOCK" position, three plastic lips, each located above a plastic pin, act like clamps pulling the reel against the bottom rim of the turntable (9B).

The portion of the turntable to which the reel is secured rotates about another part of the turntable which is attached to the magazine cover. The rotating portion contains a coupling shaft (9B) to connect it with the tape recorder drive motor when the magazine is joined to the recorder.

To remove a tape reel, the operator again places his fingers against the "LOCK"-"RELEASE" ring. He pushes down upon the ring, causing it to move toward the magazine cover. Then he rotates the ring to the "RELEASE" position. This allows the plastic lips to move toward the center of the turntable, thus releasing their grip on the tape reel. The operator may now pull off the reel.

The operation of the plastic lips can be seen in the two partially cut away views of the turntable in Exhibit 10. The lips and adjacent pins are parts of an integral plastic molding. The plastic is flexible, allowing the lips to hinge about the pins which are rigidly attached to the turntable. One side of the lips rests against the "LOCK"-"RELEASE" ring. The ring has a varying cross-section which, as the ring is rotated, acts like a cam and pushes the lips away from the center of the turntable. Attached to each lip is a spring that forces the lip against the ring, thereby causing the lip to follow the motions of the cam surface.

As viewed in Exhibit 10, the "LOCK" - "RELEASE" ring is located higher in the turntable while in the "LOCK" position than it is in the "RELEASE" position. Due to this change of location, the ring pushes the lips away from the turntable center while in the "LOCK" position, and it allows the lips to move towards the turntable center when it is returned to "RELEASE" position. The ring has on its perimeter, three equally spaced protruding screws (9D). These screws ride in slots located on the sides of the turntable (9B), thereby holding the ring in the turntable and guiding it between "LOCK" and "RELEASE" positions. A spring washer located below the ring (Exhibit 10) applies pressure to the ring. Thus, it holds the ring in the position to which it is set and indirectly applies pressure to the clamps when they are in the "LOCK" position.

A second portion of the supply turntable is directly attached to the magazine case. A part of this unit is a cylinder which serves as a mount for a ball bearing on which the outer portion of the turntable rotates. Alignment of the stationary part is assured by a dowel pin which fits in a hole in the magazine. Fastening of the stationary part is done with three screws that pass through the magazine and thread into a flange on the part. The outer portion of the turntable is secured to the stationary portion with a snap ring.

The coupling shaft, which connects the rotating part of the turntable to the recorder drive motor is screwed to the top side of the supply turntable (Exhibit 11). When the tape magazine is joined to the recorder, this coupling shaft meshes with a connection on the recorder (Exhibit 7). If the shaft is not initially in the proper angular orientation to mesh with the recorder connection, it is forced back toward the supply turntable compressing a supporting spring (9H). When the recorder drive motor is turned on, the recorder coupling rotates to a mesh position, and the shaft, pushed by its supporting spring, joins with the coupling.

A cross-section drawing of the supply turntable is shown in Exhibit 12.

The takeup turntable is similar to the supply turntable, but it has a hollow coupling shaft to allow the shaft of the supply turntable to pass through. The reason for this difference in design is indicated by Exhibit 14. In this exhibit, we see a partially opened magazine with the supply turntable on the left. The turntables are positioned so that, when the magaine is closed, the supply turntable coupling shaft must pass through a hole in the center of the takeup turntable coupling shaft before connecting with the recorder drive motor. The ends of the two coupling shafts can be seen from the outside of the magazine (8) as they would be positioned with the magazine closed. The coupling on the recorder, into which these shaft ends fit, consists of a center part that joins to the supply shaft and a concentric ring that joins to the takeup shaft. The coupling ring and center coupling are not connected to each other and each may turn at a different speed (7). Dimensions of the supply and takeup recorder couplings are given in Exhibits 15 and 16.

Since the hollow takeup shaft may not initially mesh with the recorder coupling, it is spring loaded and engages the coupling in the same way as did the supply shaft. A cross-section view of the takeup turntable is shown in Exhibit 13.

Materials for the supply turntable cost PI about $77, and materials for the takeup turntable cost about $82. It takes about half an hour to assemble a turntable, and the labor cost for this is $3.50 per turntable. PI sells a supply turntable for $94 and a takeup turntable for $97. Replacement charges for some of the individual parts are as follows: "LOCK" - "RELEASE" ring, $3.50; spring washer for "LOCK" - "RELEASE" ring, $2.50; plastic pin and lip, $1.00; plastic lip return spring, $1.00; matched pair of supply bearings, $25.00; matched pair of takeup bearings, $42.00.

The Need for a Better Hold-down Mechanism

Functionally, the present hold-down mechanism for the PI-200 series recorders is, in the opinion of PI engineers, generally satisfactory. Although turning the locking ring is hard on fingernails, the hold-down mechanism has no loose pieces, operation is fast and simple, opportunity for human error is relatively low, and it safely secures the tape reels. However, PI engineers feel that its manufacturing cost is undesirably high. The large number of turntable parts and the precision machining of the magazine hinge required to maintain proper coupling shaft alignment contribute greatly to high cost. If the eccentricity of the turntables is not kept below approximately .010 inches, the reels may "chatter" during rewinding, and "wow", a periodic variation in the frequency of recorder or reproduced signal, may occur. In the present magazine design, the supply reel has the worst fit since, statistically, tolerances in the hinge and supply turntable dimensions will cause the supply turntable to be positioned less accurately than the takeup turntable. However, proper supply turntable location is more essential to a good recorder performance than takeup turntable location. More eccentricity or irregularity of takeup reel rotation is tolerable from the frequency stability point of view since the capstan and pressure roller isolate such variations from the tape heads. Slight changes of tension in the tape between the capstan and takeup reel are not propagated to tape on the heads. Therefore, tolerance buildups in a good tape transport device should have less effect on the location of the supply turntable than that of the takeup turntable.

The hold-down knob initially designed for this tape magazine was a threaded ring which screwed onto the turntable with the aid of a spanner wrench. Customers were dissatisfied with the spanner wrench because it was easily lost, and reel changing was slow. To remedy this complaint, subsequent knobs had an irremovable grip shown in Exhibit 17. The semicircular piece was embedded in the knob during recorder operation. This knob was relatively inexpensive, but since it was a loose piece and time-consuming to use, the present hold-down mechanism was designed. At a high cost, the present design allows faster reel changing and eliminates loose pieces.

PI engineers agree that a new hold-down mechanism design must utilize the stacked reel, tape magazine concept. The ability to change reels on 200 series recorders without re-threading tape must also be preserved.

Tape Recorder Design Considerations[1]

Proper placement of tape on the heads is essential. The quality of magnetic tape recording and reproducing deteriorates with any spacing between the tape and heads; during recording the signal may fade out, and when reproducing, there will be a loss in frequency response. In most high quality recorders two guide posts hold the tape against the heads and insure proper tape placement.

Flutter may be caused by anything in the recorder which affects tape velocity. The periphery of a capstan mounted on its bearing must have an eccentricity no larger than .0002 inches to prevent excessive flutter. The capstan shaft must have enough resistance to corrosion and wear to maintain this tolerance. Consequently, capstans are usually made of stainless steel. As the capstan diameter (approximately 3/8" in PI-200 recorders) increases, undesirable capstan bending decreases; however, in most tape recorders, reel drive mechanism costs increase with capstan diameter, thus requiring a compromise between cost and bending.

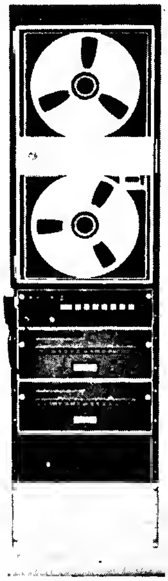
If the tape reels are off center, tape tension will not be uniform throughout a reel revolution since constant torque supplied by the reel drive motors will act on the tape through a varying moment arm. This variation in tape tension may cause flutter. If the reels scrape against the tape, flutter will also occur. Such tape disturbances are, however, partially blocked from the heads by idlers. If the eccentricity of an idler is not less than .0003 inches, it may cause more flutter than it eliminates. The idler diameter and area of tape contact must be chosen to prevent slippage between the idler and tape.

Mounting plates should be sufficiently rigid to assure a natural resonance above 300 cps -- or certainly higher than the 60 and 120 cps vibrations emitted from the drive motors. Mounting plate flexure near idlers, heads, or capstan can cause flutter and may destroy alignment between these components needed to guide the tape properly. To assure proper tape guidance, close tolerance must be held on the perpendicularity and flatness of all components in the tape track such as turntables, idlers, capstan, and heads. The diameter of all tape guides, either rotary or fixed, should not be too small (3/16" being the smallest guide post diameter on PI-200 recorders), and guide widths must be held to close tolerances, usually within .002 inches of the nominal tape dimension and preferably less. Most tape is cut to a tolerance of 0 to 4 mils under the nominal dimension. Excessive tape tension may result in tape breakage or deformation. Braking torques for 1/2" tape should not exceed 40 oz.-in. Tape threading is generally easier if tape is wrapped around

[1]Based upon the publication, Basic Concepts of Magnetic Tape Recording, Copyright 1960 by Ampex Corporation.

idlers or guide posts rather than dropped through a slot. The highest efficiency in threading tape would be provided by a transport that had a simple path from supply to takeup reel without being threaded between slots or behind idlers and guides.

Tape wrap around the heads should be minimized to avoid large frictional forces between the heads and tape. Depending on tape flexibility and head dimensions, a large tape wrap may result in the tape bowing out at the head apex and losing contact with the gap. A wrap of 4 to 6 degrees on each side of the heads is often used successfully. Sharp tape bends around the idlers of small diameter may cause measurable losses of recorded high frequencies during playback; however, tape should wrap around idlers enough to provide solid coupling. The number of components contacting the tape should be minimized to limit friction loss and tape wear.



ADVANCED LABORATORY RECORDERS

PI-400A The PI-400A is a high-performance instrumentation recorder designed for use in data acquisition and reduction centers, for the laboratory, and for general-purpose application requiring a high order of accuracy and precision. The PI-400A offers the fundamental advantages of a low inertia, high-torque drive system, and incorporates a number of refinements and advancements in technique, including crystal-controlled tape speed, electronic-servo-control of tape tension, and facility for automatic operation within a digital system. Pushbutton controls actuate logic circuits which are programmed to guide the transport from any operating mode to any other operating mode, thereby eliminating the factor of human error in control of the transport.

A highly practical convenience feature is total accessibility of all component units of the recorder, even during operation. For example, the entire tape transport may be rotated on vertical pivots while recording or reproducing.

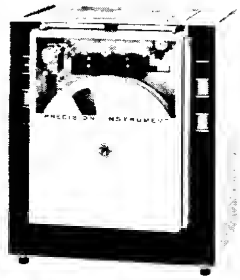
Tape accommodated ½" or 1" tape.

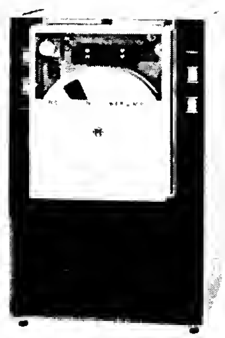
Tape Speeds 1⅞, 3¾, 7½, 15, 30, and 60 ips, all 6 speeds electrically selectable, for recording or reproducing in both directions.

Recording Modes Direct: FM carrier; PDM; DIGITAL.

Data Bandwidth Direct: up to 250 kc at 60 ips; FM: 20 kc at 60 ips.

$25,000





PORTABLE/COMPACT RECORDERS

PI-200 Series These precision-designed recorders offer performance usually associated only with laboratory instruments of much larger size and greater expense. First instrumentation recorders to utilize all-solid-state electronics, they are widely used both as fully portable field units and in rack-mounting applications in submarines, aircraft, instrumentation vans, and in data laboratories.

PI-200 recorders are available in ½" (7-channel) and 1" (14-channel) models, occupying 2 and 3½ cubic feet respectively. They utilize PI's unique stacked-reel tape magazine concept which not only saves space but also permits instant interchangeability of magazines without requiring rewinding of tape. Interchangeable loop magazines are also available

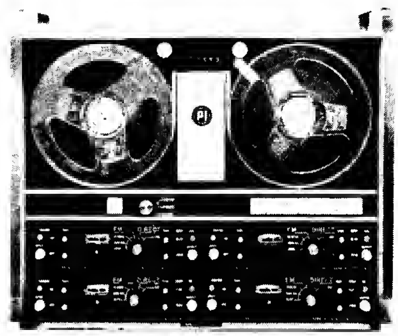
Tape accommodated ¼", ½", or 1" on standard 10½" reels.

Tape speeds Either 4 or 6 standard speeds from $1\frac{5}{16}$ through 60 ips, in ratio of 1:2:4:8:16:32; pushbutton change between any 2 speeds in 1:2 ratio.

Recording Modes Direct; FM; Digital.

Data Bandwidth Direct: 200 kc at 60 ips. FM: 20 kc at 60 ips.

$11,000



GENERAL PURPOSE LAB RECORDER

PI-6100 This unusually versatile recorder offers many advantages for recording such phenomena as biomedical parameters, process variables, transients, and other analog data occurring at frequencies up to 100,000 cycles per second. A unique feature is the ability of the instrument to compress or stretch data in the ratio of 10-to-1 and 100-to-1. Thus it could be used to monitor a process from 4 o'clock pm until 8 o'clock the next morning, for example, and the entire night's operations could be played back in 9½ minutes. Or, conversely, the recorder could capture the complex vibrations, pressure and temperature changes of an explosive detonation, and spread them out over several minutes for detailed analysis.

Other facets of the PI-6100's versatility are its FM/Direct front-panel-switchable electronics, its built-in calibration, single-channel through 8-channel operation on ¼" magnetic tape, precision closed-loop transport, and speed control comparable with that of much more costly machines.

Tape Accommodated ¼", on standard 7" reels.

Tape Speeds 37.5 ips, 3.75 ips, and .375 ips.

Recording Modes Direct and FM.

Data Bandwidth Direct: To 100 kc. FM: To 10 kc.

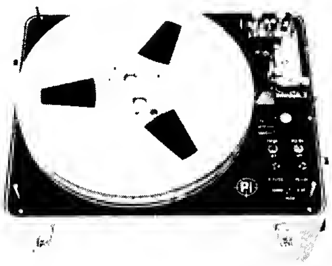
Power 105-230 VAC, 50-400 cps or + and −12 VDC; optional 12 VDC or 28 VDC.

$9,000

Exhibit 1 - PI Products

(All prices are approximate)

Courtesy of PI



LONG-TERM MONITORING RECORDER

PI-5100 For recording such variables as earthquakes, underground shockwaves, and related geophysical phenomena; and for long-term monitoring of industrial and process variables, the PI-5100 offers the ability to record for as long as 32 days without attention. It is designed to function in a variety of environments, at temperatures from 20°F. to 140°F., in relative humidities to 100%, and at altitudes up to 15,000 feet.

The PI-5100 utilizes a stacked-reel design which enables the use of 14" diameter reels and yet allows the entire recorder to be fitted into a carrying case measuring only 18½" x 15" x 10". Weight, including tape, is 35 pounds, affording easy portability. The case is sealed against moisture and can be carried in the open in any weather.

As many as 7 channels of information may be recorded simultaneously. Input requirements are 1 volt RMS into 10K ohms. Power required is 12 volts dc, with power drain of 7.5 watts maximum during operation.

Tape accommodated ½", on standard 10½" or 14" reels.

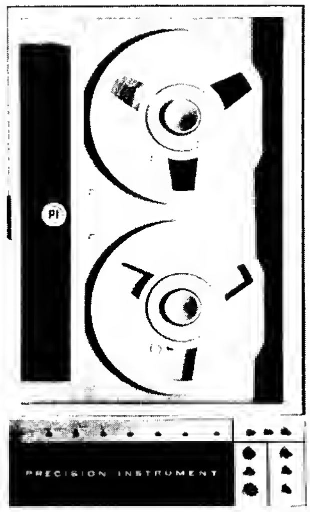
Tape speed* 15/160 ips.

Recording Mode FM.

Data Bandwidth* DC-17 cps.

* With modification, can be as slow as 15/480 ips (bandwidth of 10 cps) or as fast as 15/16 ips (bandwidth of 170 cps) with recording times of 32 days and 25½ hours respectively.

$7,000



INCREMENTAL RECORDER

RSL-150-7 The incremental recorder produces computer-compatible tapes from data received either synchronously or asynchronously (randomly). The recorder accepts pulses at widely varying rates and produces a standard NRZ digital tape with a uniform packing density of 200 bits per inch (556 BPI optional). When recording the output of a teletypewriter, for example, the unit eliminates the need for making an intermediate punched paper tape by converting the random pulse data into a magnetic tape format usable directly by the computer.

Upon receipt of a digital character, the RSL-150 records it and immediately advances the tape 1/200 of an inch while awaiting the next character. Resultant bit packing density is uniform whether the characters arrive 1 per month or 100 per second.

The RSL-150-7 is also available in a model with Read/Write capability.

Tape accommodated ½" tape on 10½" reels.

Channels 7 tracks, including parity and clocktracks, on ½" tape.

Input requirements −12 volt pulses with 5 μsec. rise time, occurring at any rate from 0 to 100 per second.

Power 115 volts ±10%, 48 to 62 cps.

Size Uses 30 inches of standard rack space.

$6,000

TELEVISION RECORDER

PI-3V For use in medical, military, industrial, and educational television applications, the PI-3V records more than 1½ hours of sight and sound on a single reel of 1" tape. Playback may be immediate, or days or years later, once or hundreds of times; and the tape may be simply erased and re-used when the recorded program material has outlived its usefulness.

For detailed study of a portion of the televised material, the PI-3V's "Stop-Motion" feature enables the operator to "freeze" a single picture and thus observe it for several minutes. This feature is also useful in studying fast transients displayed on an oscilloscope.

Tapes recorded on one PI-3V recorder are completely interchangeable. The recorder is compatible with EIA standard or industrial sync, and operates from either vidicon or image orthicon TV cameras.

The PI-3V, because it uses 1" tape and advanced all-solid-state circuitry, is extremely compact and readily transportable (only 75 pounds) by one man. An entire TV system — including camera, monitor, and the PI-3V — can be put into the rear seat of a compact car. The PI-3V requires only 350 watts of power — plugs into any 110-volt, 50 or 60 cycle wall socket.

$9,000

Exhibit 1 (cont.)

Courtesy of PI

Supply Reel

Takeup Reel

Exhibit 2 - Tape Magazine

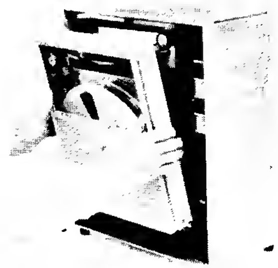
Courtesy of PI

REMOVABLE TAPE MAGAZINES

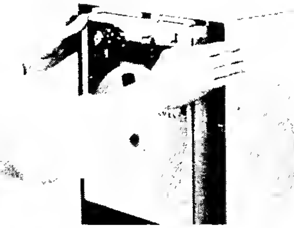
Simple, rapid tape change. The removable magazine, a unique feature of P.I. recorders, enables an operator to change reels of tape in a few seconds.

The tape magazine opens like a book to accept reels. The reel hold-down mechanism, an integral part of the magazine, locks or releases reels by a simple 90° twist. Tape may be threaded from one reel to the other while in this position.

The closed magazine, containing tape threaded from reel to reel, is ready to be installed on the face of the recorder.



The base of the magazine is simply positioned on a supporting bar at the bottom of the recorder.



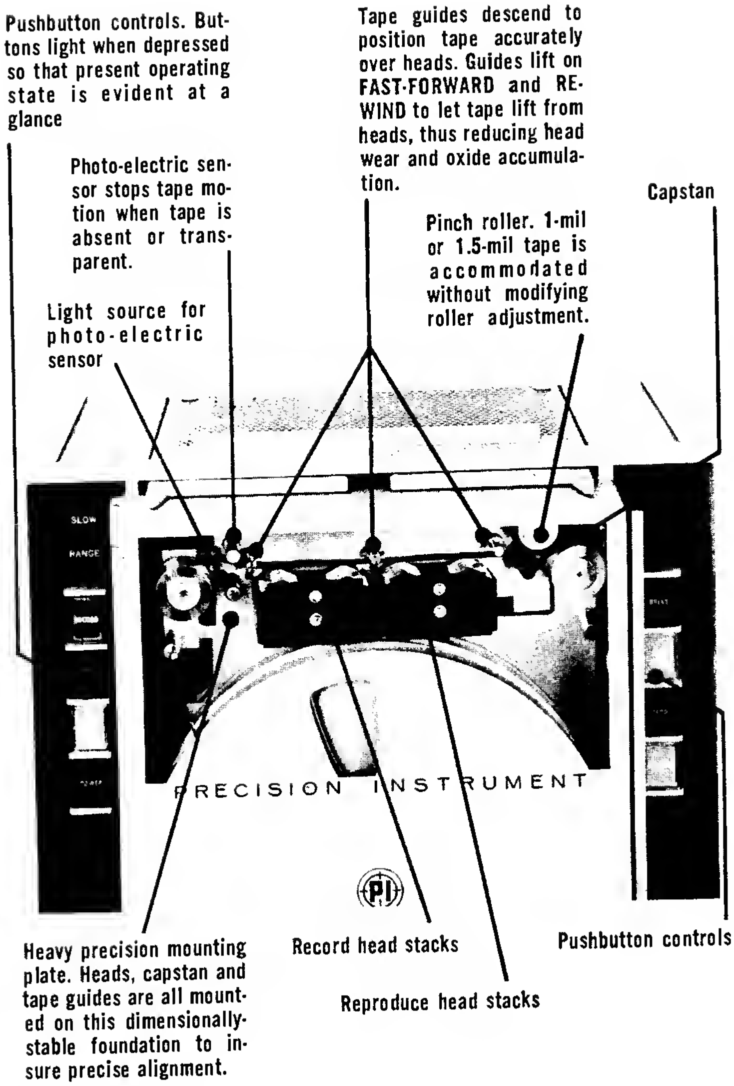
Then the top is swung forward until the magazine snaps into place. This motion automatically threads the tape over the heads, so the recorder is ready to operate at the push of a button. The magazine may be removed with tape fully or partially run and replaced with another loaded magazine.

As an alternative, reels may be easily removed and other reels mounted with the magazine in place.

Continuous, long-term recording. The quick magazine change makes it possible to record reel after reel of data with only a few seconds interruption between reels. In continuous monitoring applications this feature may eliminate the need for two recorders, one of which is employed to record data while the other is being loaded.

No tape threading errors. The tape slips automatically into the proper path when a loaded magazine is snapped into place.

Reels protected during handling. The sturdy magazine prevents precision reels from being damaged during routine handling procedures.



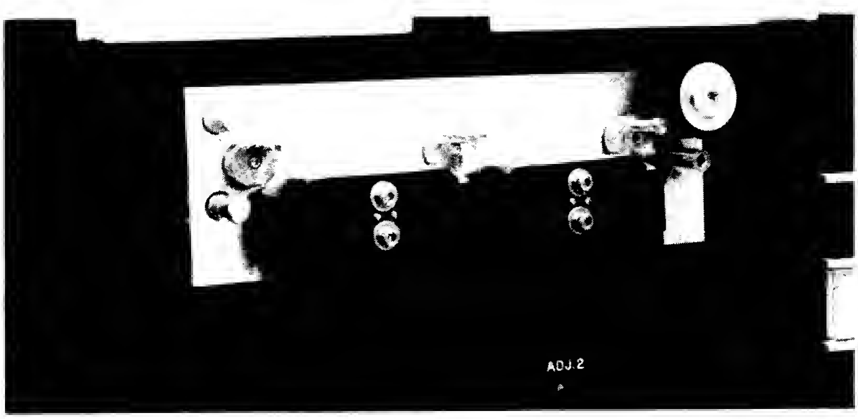


Exhibit 3 - Precision Drive Assembly

Courtesy of PI

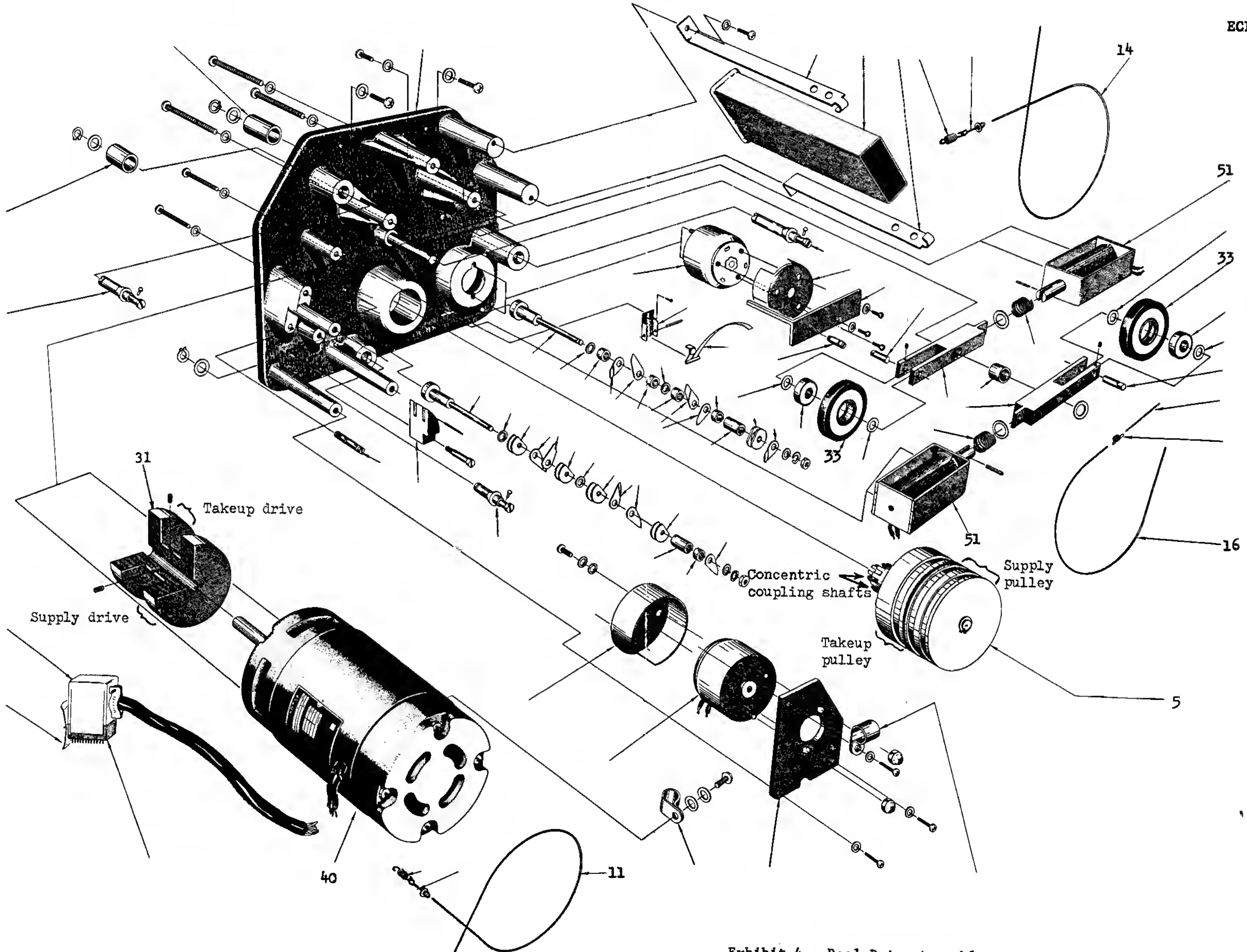


Exhibit 4 - Reel Drive Assembly

Courtesy of PI

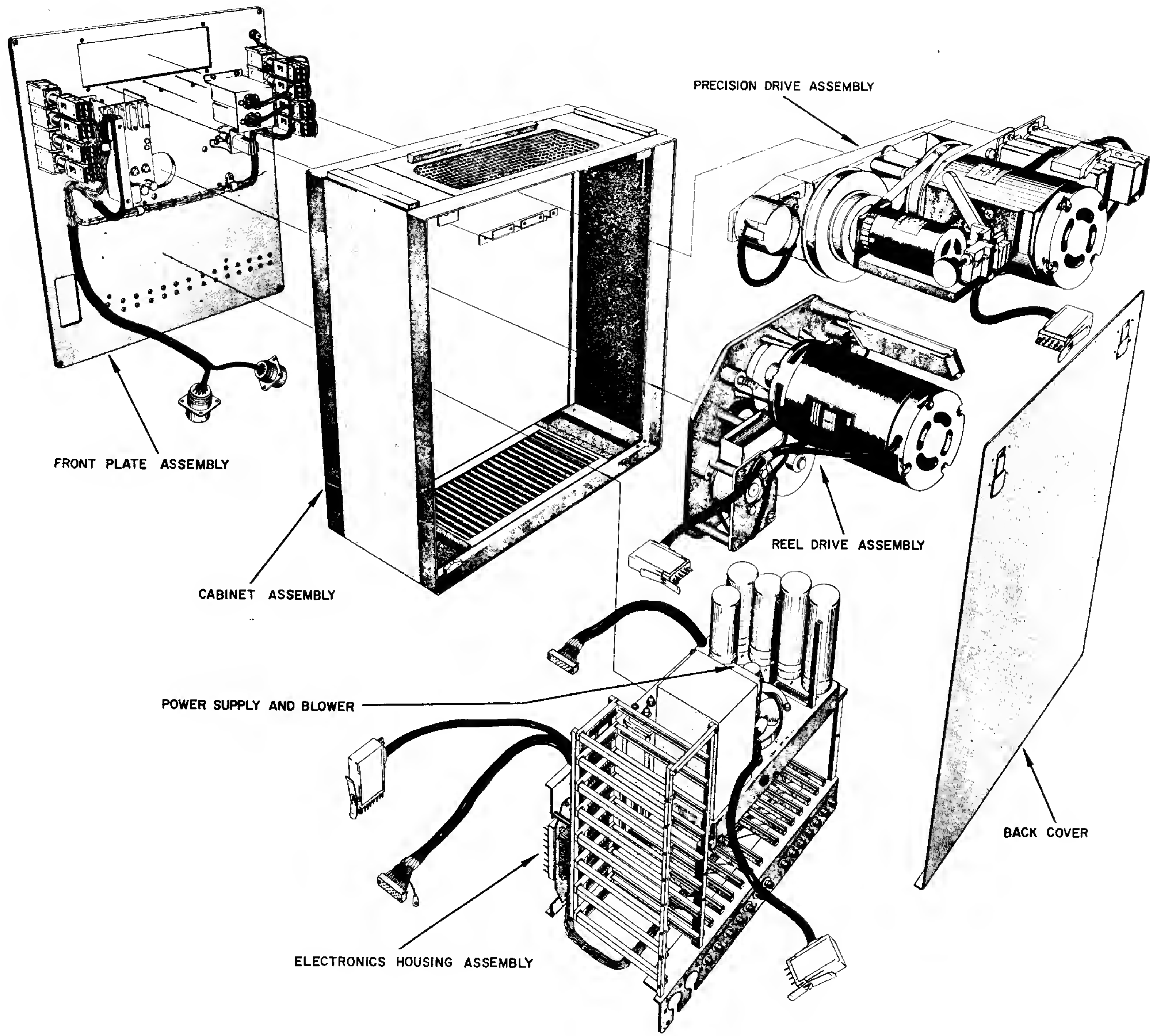
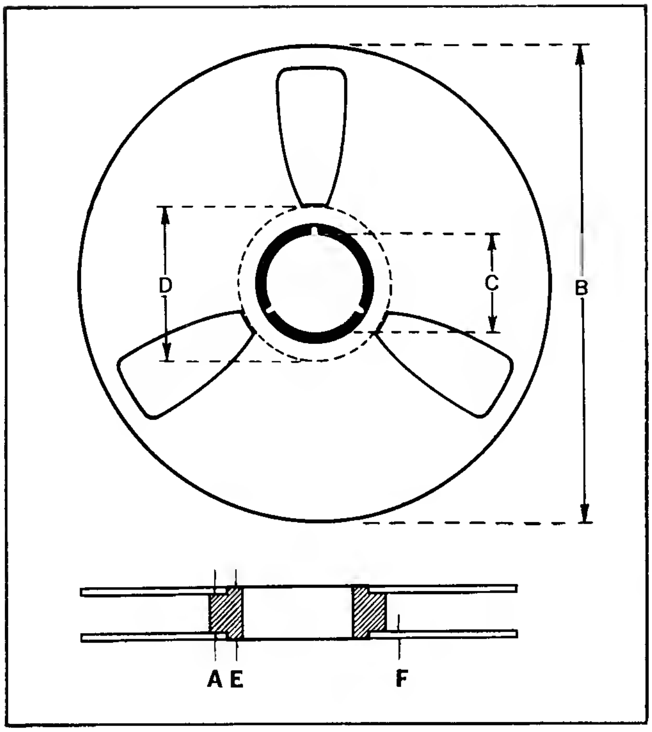


Exhibit 5 - Major Components   Courtesy of PI



HEAVY DUTY (IRH) PRECISION REEL — WIDTH 1/4 IN.	¼-IRH-10½		¼-IRH-14	
	10½ INCH		14 INCH	
	Dimension (Inches)	Tolerance (Inches)	Dimension (Inches)	Tolerance (Inches)
A. TRAVERSE WIDTH OF HUB*	.270	+.002 −.000	.270	+.002 −.000
B. REEL OUTSIDE DIAMETER	10.500	+.010 −.000	14.000	+.010 −.000
C. HUB INSIDE DIAMETER**	3.000	+.003 −.000	3.000	+.003 −.000
D. HUB OUTSIDE DIAMETER** (Exclusive of Friction Ring)	4.500	±.005	4.500	±.005
E. REEL OVER-ALL WIDTH	.462	+.003 −.000	.462	+.003 −.000
F. FLANGE THICKNESS	.090	+.002 −.004	.090	+.002 −.004
WEIGHT EMPTY, OZ.	25		41	
WEIGHT FULL, OZ.	38†		67††	
MOMENT OF INERTIA, Empty, oz.-in.-sec.²	0.9		2.6	
MOMENT OF INERTIA, Full, oz.-in.-sec.²	1.4†		4.2††	
REEL Concentricity, Inches (Total Indicator Reading)	.010		.010	
DISTANCE Between Flanges, Inches	Dimension A +.020 −.010		Dimension A +.030 −.010	

HEAVY DUTY (IRH) PRECISION REEL — WIDTH 1/2 IN.	½-IRH-10½		½-IRH-14	
	10½ INCH		14 INCH	
	Dimension (Inches)	Tolerance (Inches)	Dimension (Inches)	Tolerance (Inches)
A. TRAVERSE WIDTH OF HUB*	.520	+.002 −.000	.520	+.002 −.000
B. REEL OUTSIDE DIAMETER	10.500	+.010 −.000	14.000	+.010 −.000
C. HUB INSIDE DIAMETER**	3.000	+.003 −.000	3.000	+.003 −.000
D. HUB OUTSIDE DIAMETER** (Exclusive of Friction Ring)	4.500	±.005	4.500	±.005
E. REEL OVER-ALL WIDTH	.712	+.003 −.000	.712	+.003 −.000
F. FLANGE THICKNESS	.090	+.002 −.004	.090	+.002 −.004
WEIGHT EMPTY, OZ.	28		45	
WEIGHT FULL, OZ.	54†		97††	
MOMENT OF INERTIA, Empty, oz.-in.-sec.²	0.9		2.6	
MOMENT OF INERTIA, Full, oz.-in.-sec.²	1.9†		5.9††	
REEL Concentricity, Inches (Total Indicator Reading)	.010		.010	
DISTANCE Between Flanges, Inches	Dimension A +.020 −.010		Dimension A +.030 −.010	

HEAVY DUTY (IRH) PRECISION REEL — WIDTH 1 IN.	1-IRH-10½		1-IRH-14	
	10½ INCH		14 INCH	
	Dimension (Inches)	Tolerance (Inches)	Dimension (Inches)	Tolerance (Inches)
A. TRAVERSE WIDTH OF HUB*	1.020	+.002 −.000	1.020	+.002 −.000
B. REEL OUTSIDE DIAMETER	10.500	+.010 −.000	14.000	+.010 −.000
C. HUB INSIDE DIAMETER**	3.000	+.003 −.000	3.000	+.003 −.000
D. HUB OUTSIDE DIAMETER** (Exclusive of Friction Ring)	4.500	±.005	4.500	±.005
E. REEL OVER-ALL WIDTH	1.212	+.003 −.000	1.212	+.003 −.000
F. FLANGE THICKNESS	.090	+.002 −.004	.090	+.002 −.004
WEIGHT EMPTY, OZ.	36		52	
WEIGHT FULL, OZ.	88†		156††	
MOMENT OF INERTIA, Empty, oz.-in.-sec.²	0.9		2.6	
MOMENT OF INERTIA, Full, oz.-in.-sec.²	2.9†		9.1††	
REEL Concentricity, Inches (Total Indicator Reading)	.010		.010	
DISTANCE Between Flanges, Inches	Dimension A +.020 −.010		Dimension A +.030 −.010	

*Mounting surfaces of hub are parallel within .0002 inch per inch and are perpendicular to center axis within 2 minutes of arc.

**Hub inside and outside diameters are concentric within .002 inch T.I.R.

†Full condition based on 2500 ft. roll of standard No. 408 or No. 498 tape with E factor of ⅜ inch. Figures for most other tapes are within ± 10% of quoted figures.

††Full condition based on 5000 ft. roll of standard No. 408 or No. 498 tape with E factor of ½ inch. Figures for most other tapes are within ± 10% of quoted figures.

Exhibit 6 - Precision Reel Dimensions

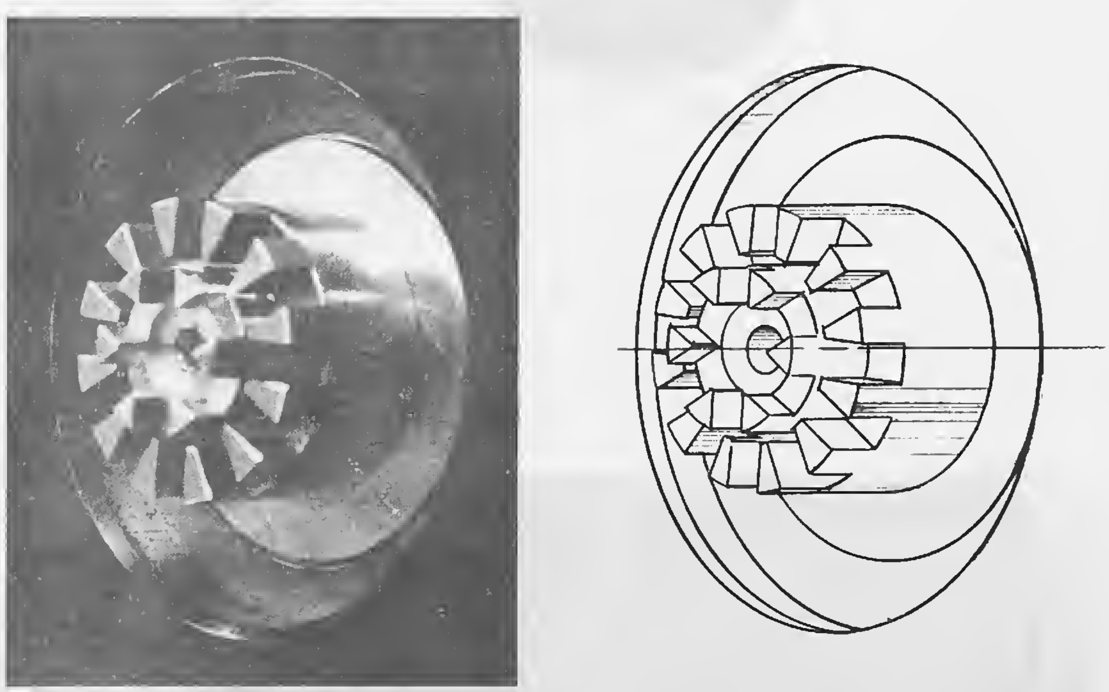


Exhibit 7 - Reel Drive Shafts
and Magazine Positioning Hole

Courtesy of PI

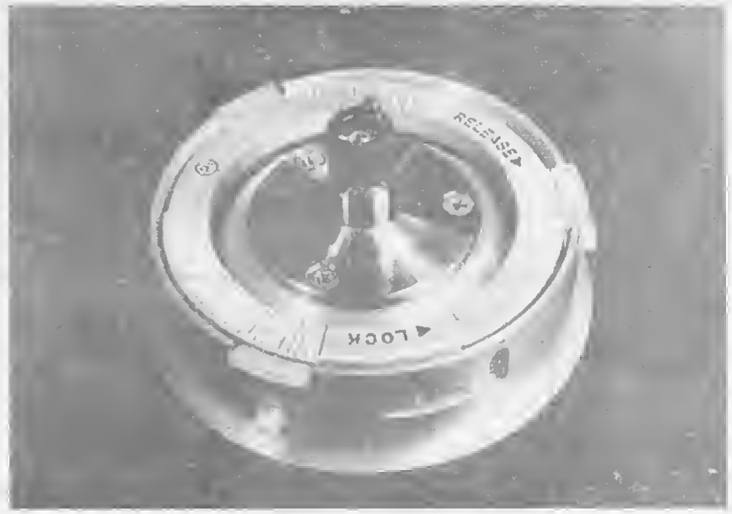
View of Magazine Showing Positioning
Ring and an Early Hinge

Close-up of Positioning Ring
and Magazine Couplings

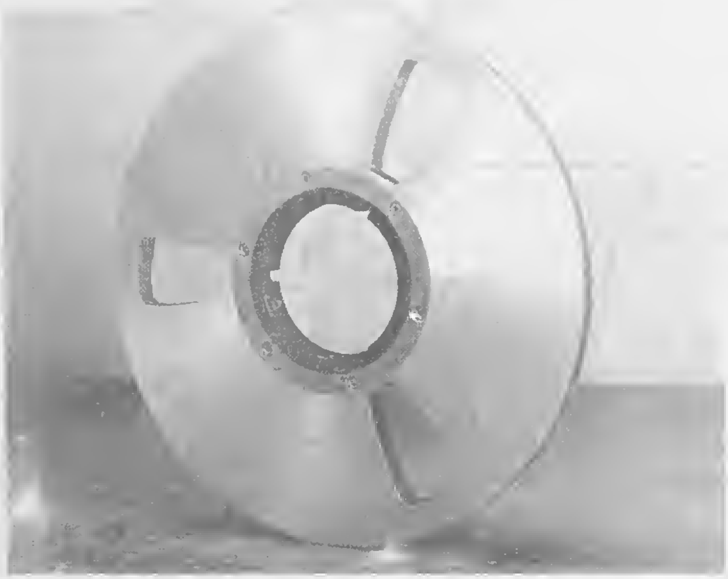
Exhibit 8

Courtesy of PI

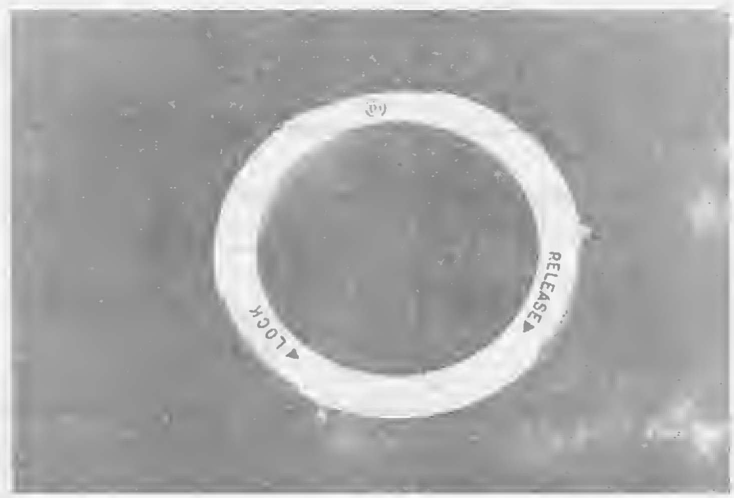
A: Supply Turntable Attached to Magazine



B: Supply Turntable



C: Tape Reel



D: LOCK - RELEASE Ring

Courtesy of PI

Exhibit 9 - Supply Turntable

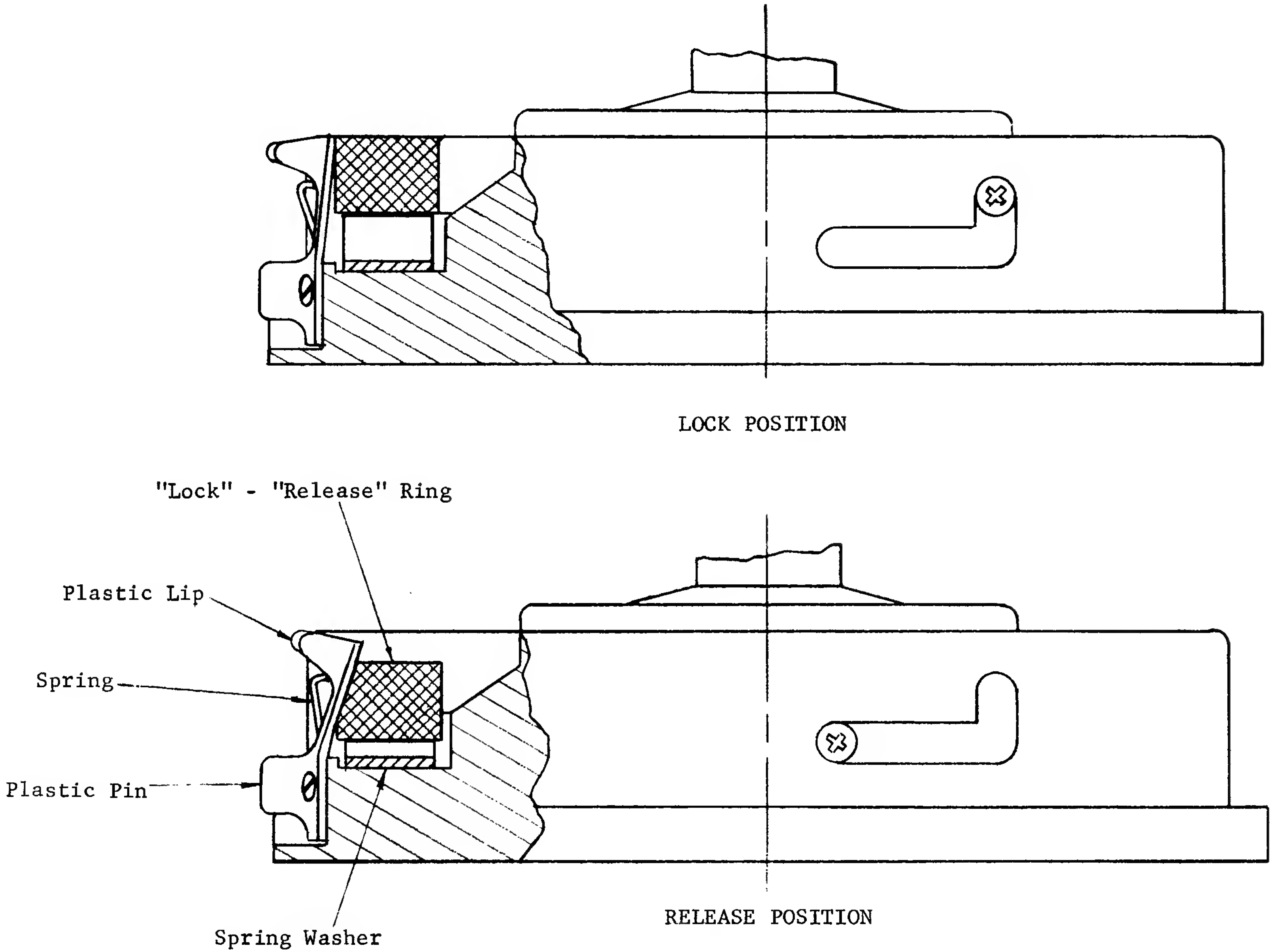


Exhibit 10 - Reel Locking Mechanism

Courtesy of PI

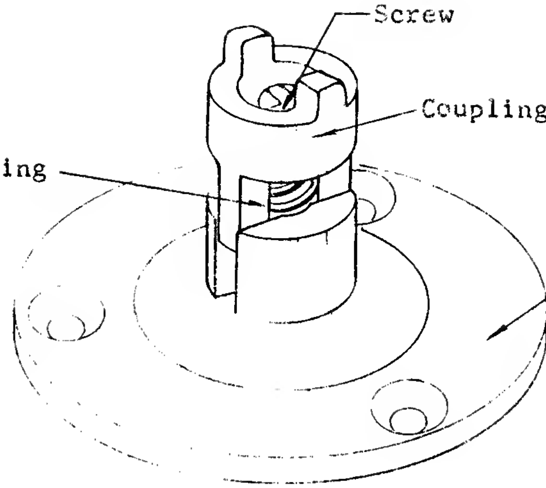


Exhibit 11 - Supply Coupling Shaft Assembly

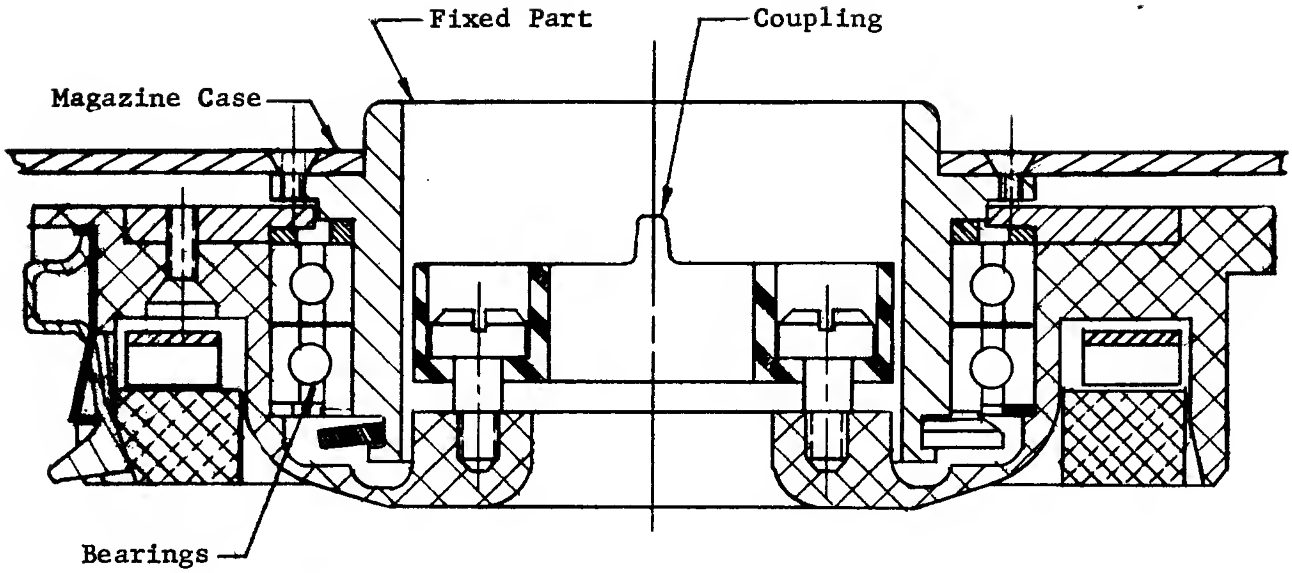


Exhibit 13 - Takeup Turntable Cross Section

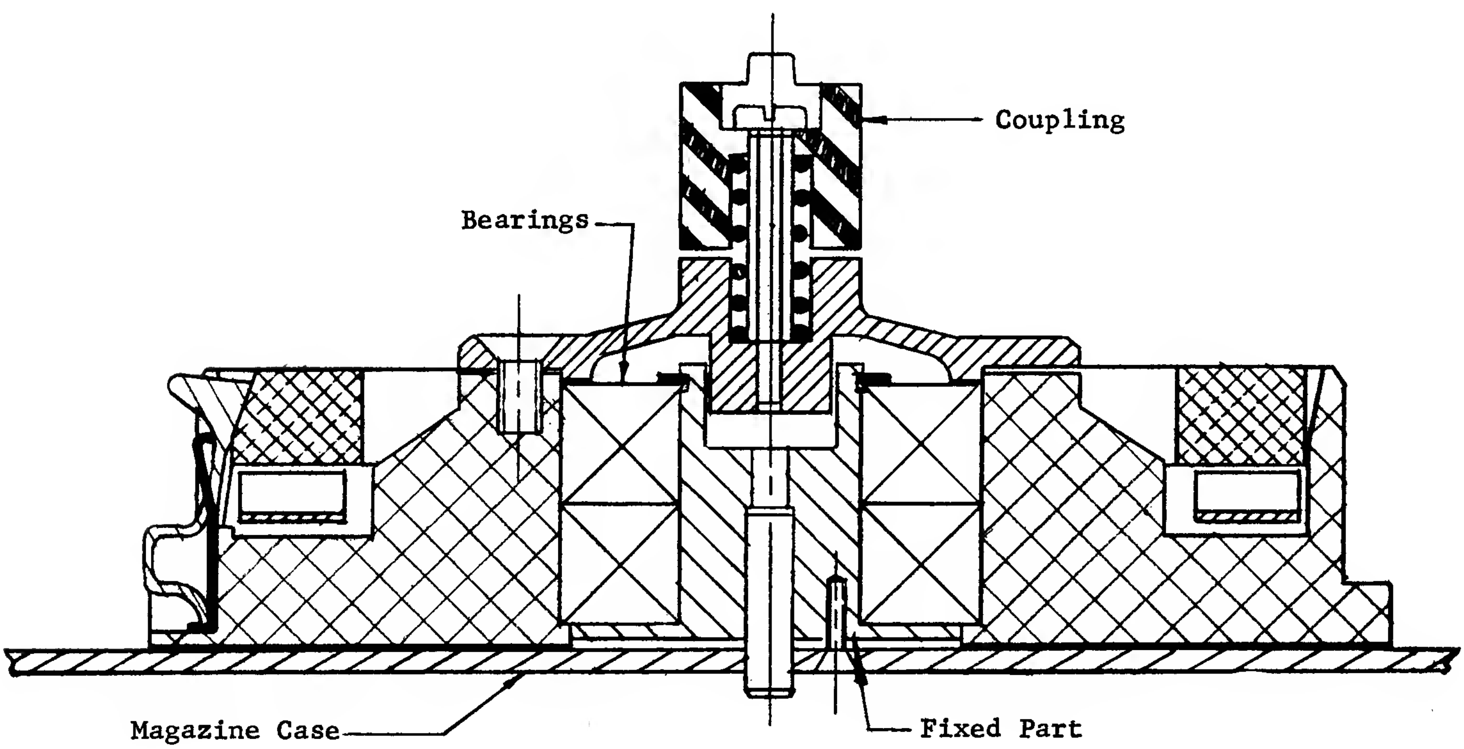


Exhibit 12 - Supply Turntable Cross Section

Courtesy of PI

Exhibit 14 - Partially Opened Magazine

Courtesy of PI

Scale: 2X

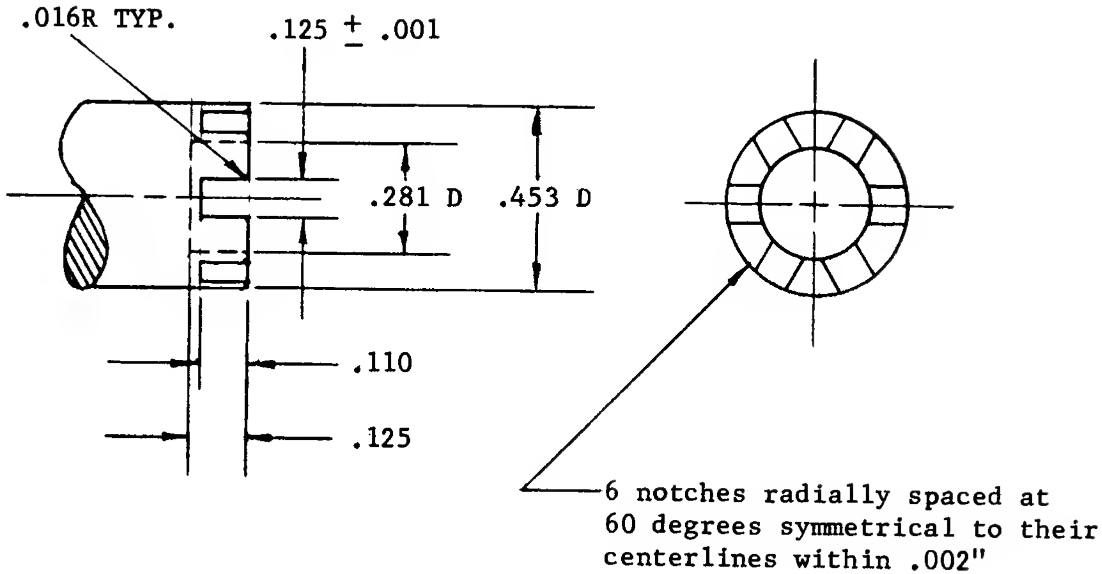


Exhibit 15 - Supply Coupling Shaft

Courtesy of PI

Scale: 2X

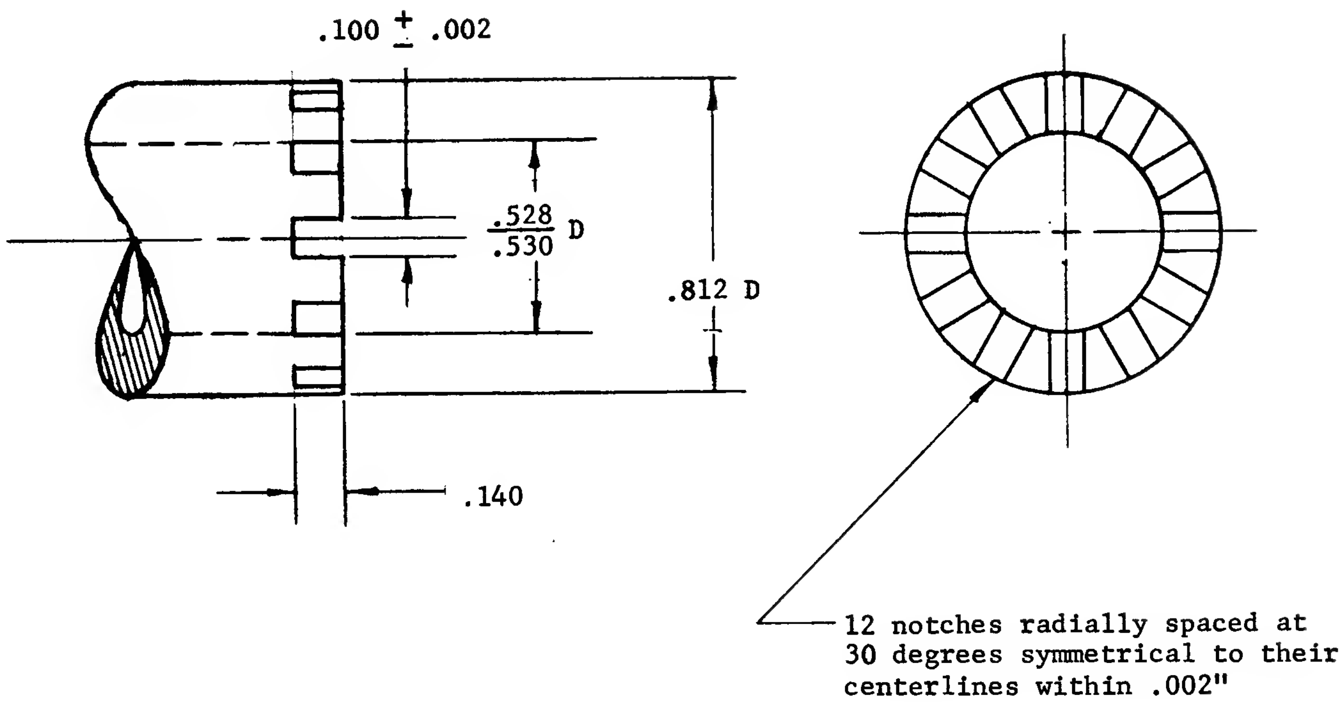


Exhibit 16 - Takeup Coupling Shaft

Courtesy of PI

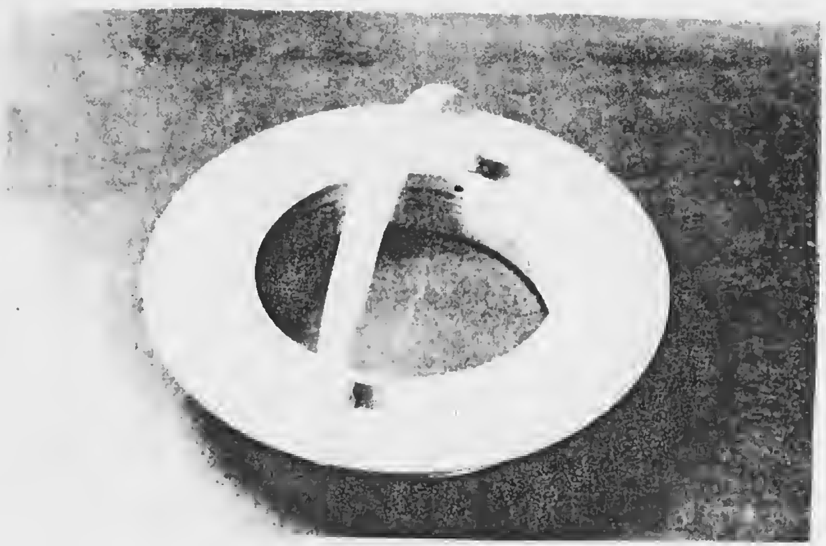


Exhibit 17 - An Early Hold-Down Knob

Courtesy of PI